The Effects of Policies and Measures for Vegetation Fire Events on Air Pollution and Human Health in Thailand: A Literature Review and Data Integration

Athicha UTTAJUG*

Department of Hygiene, Graduate School of Medicine, Hokkaido University
Kita 15, Nishi 7, Kita-ku, Sapporo, 060-8638, Japan
**Email: u.athicha@med.hokudai.ac.jp*

Abstract

Air pollution from vegetation fire events in Thailand is a serious public health concern, particularly in the upper northern region. In response, several policies and measures have been implemented to control such fire events in this area. The objective of this study was to provide an update on the existing and current policies on vegetation fire events, their effects on air pollution and their influence on health by conducting a literature review and integrating the relevant information. The findings reveal that strict regulations prohibiting burning have had a significant effect on both air pollution and health after implementation compared to other policies. Despite increased evidence of short-term health effects from air pollution from vegetation fires, there is a need for additional research on chronic effects as well as studies that consider longer-term interventions through policies and factors that might affect exposure levels when examining the beneficial effects of policies on health impacts. Filling these knowledge gaps will help better define the potential health impacts of policies on vegetation fire events and further identify specific preventive interventions to promote health in this region in the future.

Key words: air pollution, health effects, policy, upper northern Thailand, vegetation fire events

1. Introduction

Air pollution from vegetation fire events is a serious environmental and health problem in Southeast Asia (Vadrevu *et al*., 2019). The smoke from these fires affects not only local areas, but also neighboring parts of Myanmar, Vietnam, Laos, Cambodia, Thailand and other countries (Yin *et al*., 2019). A previous study demonstrated that air pollution from vegetation fires not only degrades the local air quality but is also a common transboundary pollutant (Targino *et al*., 2013). The main causes of these fires are human activities and climate factors. In upper northern Thailand (UNT), people often use fire to clear land in forested areas (32%) or burn agricultural waste (17%) (Forest Fire Control Division, 2003). Moreover, climate phenomena like El Nino also increase the fire risk by inducing hot, dry conditions in this region (Thirumalai *et al*., 2017).

Exposure to air pollution from vegetation fire events poses health risks in UNT. Most studies have consistently found an association between air pollution from vegetation fires and respiratory morbidity (Mueller *et al*., 2020; Uttajug *et al*., 2021) and mortality (Pothirat *et al*., 2019). A previous study has estimated that approximately 130,000 hospital visits for respiratory diseases (1.3% of total visits) were attributable to smoke haze from 2014 to 2018 (Uttajug *et al*., 2022a).

Since 2002, Thailand has been taking various measures to prevent and mitigate haze problems at the national and regional levels. Thailand has also collaborated with other member countries in the Association of Southeast Asian Nations (ASEAN) to address transboundary haze under the ASEAN Agreement on Transboundary Haze Pollution (AATHP), which was signed in 2002 and entered into force in 2003. The agreement aims to prevent and control transboundary haze pollution through cooperative activities and mutual assistance among ASEAN members (Charusombat, 2023). As part of the national haze action plan launched in 2004, Thailand has introduced several actions to reduce air pollution from fire events. These have included promoting zero-burning campaigns and imposing strong penalties for prohibited burning in forest areas (Uttajug *et al*., 2022b). These measures have had beneficial impacts on air pollution concentrations (Yabueng *et al*., 2020) and health effects (Uttajug *et al*., 2022b).

Previously, the studies reviewed have focused on the health effects of exposure to air pollution from vegetation fires (Cheong *et al*., 2019; Phung *et al*., 2022; Ramakreshnan *et al*., 2018), but none have demonstrated how policies on vegetation fire events affect air pollution and human health. The objective of this study was to review the literature on existing and current policies or measures against vegetation fire events and their effects on air pollution and human health in Thailand, as well as to integrate disparate information to address the following questions:

- What are the existing current policies or measures for reducing air pollution from vegetation fire events?
- What are the priority research and information needs that can better prepare managers, policymakers and the public to reach informed decisions related to the impacts of air pollution from vegetation fire events on human health?

2. Methods

2.1 Literature Review

Relevant publications were searched from electronic reference databases (Pubmed and Web of Science) using combinations of the key terms shown in Table 1. Only full-text original or research articles related to the research questions conducted in Thailand were included. Articles focusing on reviewing other articles were excluded. Due to the scarcity of articles on policy measures for reducing vegetation fires or air pollution from fires in Thailand, both peer-reviewed and non-peer-reviewed articles were included in this study. A search using the key terms of Set 6 (Table 1) was conducted to address the first research question. To address the second research question, only epidemiological studies with implementation (Set 9) and without it (Set 8) were considered in this study.

2.2 Data Integration and Analysis

To evaluate the effectiveness of existing and current policies or measures against vegetation fire events, a report titled "Standard Operating Procedure for Northern Haze Response" (Pollution Control Department, 2019) was analyzed along with environmental and mortality information. The data were collected from 2012 to 2021 in UNT, which includes nine provinces: Chiang Mai, Chiang Rai, Phrea, Phayao, Mae Hong Son, Nan, Lamphun, Lampang and Tak.

2.2.1 Environmental Data

Daily concentrations of $PM_{2.5}$ and PM_{10} (µg/m^3) were obtained from background monitoring stations provided by the Pollution Control Department of Thailand. The data were gathered from two stations each for PM_{10} and $PM_{2.5}$, all situated in Chiang Mai Province. This location was chosen as it is representative of the UNT, given the availability of historical data. Daily average concentrations of $PM_{2.5}$ and PM_{10} were computed for each year. Fire hotspot data were obtained from NASA's Fire Information for Resource Management Systems (FIRMS), which, in brief, detects fire hotspots at a resolution of 1 km by Terra and Aqua satellites. Daily fire hotspots were summed for UNT each year.

2.2.2 Mortalities Attributable to $PM_{2.5}$

The number of mortalities attributable to $PM_{2.5}$ was estimated using UNT population data, the national mortality rate (https://data.worldbank.org/), concentration-response function (relative risk 1.004 (95% confidence interval: 1.001, 1.008), (Uttajug *et al*., 2023)) and background $PM_{2.5}$ concentration. The health burden estimation method was documented in a previous study (Uttajug *et al*., 2022a). The estimation was performed for January to April, during which intensive burning occurs in this area. It was assumed that burning events mainly emitted elevated $PM_{2.5}$ concentrations during these periods.

Table 1 Key terms and searches.

Search	Key terms and searches
Policies or measures to reduce air pollution from vegetation fire events	
Set 1	Regulation or abatement measure or campaign or law or ban or policy or control measure
Set 2	Air pollution or smoke haze
Set 3	Vegetation fire events or biomass burning or wildfire or bushfire or forest fire or fires
Set 4	Thailand or northern upper Thailand
Set 5	Publication year = 1990:2023
Set 6	Set 1 and Set 2 and Set 3 and Set 4 and Set 5
Effects of air pollution from fire events and policies on human health	
Set 7	Public health or health or morbidity or mortality or hospitalization or hospital visits or clinic visits
Set 8	Set 2 and Set 3 and Set 4 and Set 5 and Set 7
Set 9	Set 6 and Set 7

3. Results and Discussion

3.1 Existing and Current Policies or Measures to Reduce Air Pollution from Vegetation Fire Events.

A search for policies or measures on vegetation fire events found five studies (Table 2). Four of them described policies that had been implemented and some of them reported their effects on air pollution (Junpen *et al*., 2020; Kumar *et al*., 2020; Lualon *et al*., 2013; Yabueng *et al*., 2020). One study proposed alternative measures to reduce air pollution from crop residue burning (Arunrat *et al*., 2018).

Figure 1 shows how the data on policies on vegetation fire events, environmental information and health impacts from 2012 to 2021 was integrated in UNT. According to a report from the Pollution Control Department (PCD), several policies on vegetation fire events had been enforced in UNT since 2004. A national haze action plan was launched in 2004 to control open burning, but there were no data on air pollution during that period. We could not estimate the pre-2012 mortality because of the missing PM concentration data. Also, this study only examined the main policies adopted to deal with vegetation fires over time, without monitoring their actual implementation. Thus, the effects on air quality and health outcomes may have been affected by a combination of different policies or actions. In 2012, the PCD adopted the Eight-Point Plan, which included a variety of actions for reducing smoke haze from fire events. The plan involved measures such as banning the burning of agricultural residues for 80 days, preventing forest fires, promoting "burn-free villages," engaging in corporate social responsibility programs and establishing an early warning haze system among others (Lualon *et al*., 2013). The Alternative Energy Development Plan (AEDP) was also introduced to encourage the use of crop residues to

Table 2 Summary of studies on existing and current policies or measures to reduce air pollution from vegetation fire events.

Author (year)	Implemented policy	Year of implementation	Details	Effects on air pollution
Lualon *et al.* (2013)	Eight-point plan (*enforced*)	2013	Implementation of several actions to reduce smoke haze such as promoting villages free from burning, establishing an early warning, etc.	NA
Kumar *et al.* (2020)	Alternative Energy Development Plan (AEDP) (*enforced*)	2012	Using crop residues for alternative energy instead of burning them.	NA
Arunrat *et al.* (2018)	Crop-residue management (*suggested*)		Implementation of an integrated farming system, which might result in less burning.	Reduced $PM_{2.5}$ emissions
Yabueng *et al.* (2020)	Control of open burning (*enforced*)	2016	Strict implementation of the burning ban and legal enforcement of the policy	Reduction in the number of fire hotspots and PM emissions, but prolonged periods of burning still exist
Junpen *et al.* (2020)	Preharvest sugarcane treatment (*enforced*)	2019	Change of cutting conditions during harvest from burned sugarcane to fresh sugarcane.	Reduced air pollution emissions in the first year of implementation

NA: Not reported

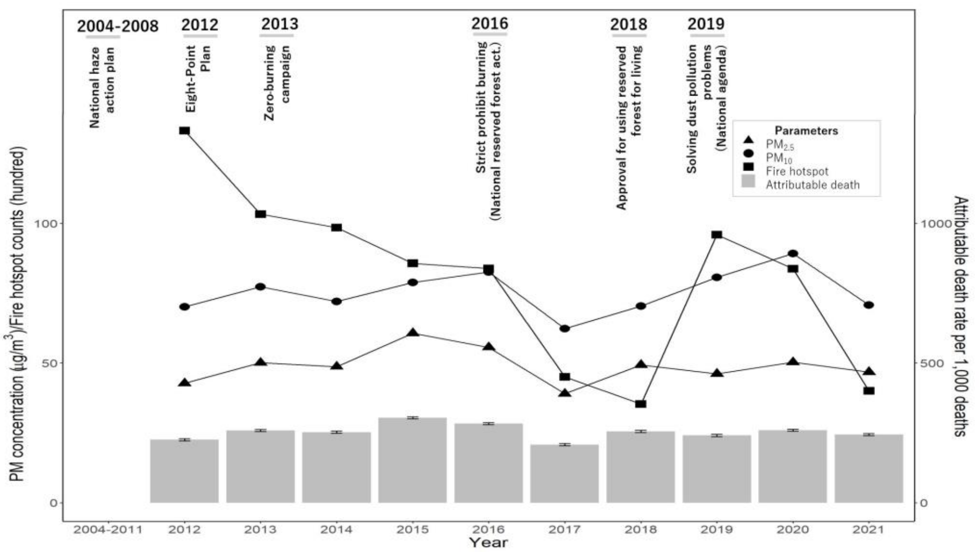

Fig. 1 Timeline of major policies/measures implemented to address vegetation fires, environmental factors and health impacts in upper northern Thailand from 2012 to 2021. It should be noted that mortality attributable to $PM_{2.5}$ before 2012 was not estimated due to lack of PM concentration measurements. The daily average concentrations of $PM_{2.5}$ and PM_{10} and numbers of mortalities attributable to $PM_{2.5}$ were estimated for January to April of each year.

produce alternative energy rather than just burning them (Kumar *et al*., 2020). However, none of the reviewed studies reported the effects of these policies on air pollution. Arunrat and his colleagues suggested that implementing an integrated farming system could reduce $PM_{2.5}$ emissions by reducing burning activities (Arunrat *et al*., 2018). These policies may have reduced fire events in UNT, as the number of fire hotspots decreased from 2012 to 2016. However, neither $PM_{2.5}$ nor PM_{10} concentrations changed during this period (Fig. 1).

In mid-May 2016, the policy on vegetation fires was strictly enforced and implemented. The National Reserved Forest Act was amended to impose severe penalties and sanctions for violations of the ban on burning in forest areas (Office of the Council of State of Thailand, 2016). In addition, zero-burning and restricted burning periods were also strictly applied in other land used in UNT (e.g., agricultural land). Figure 1 shows that the number of fire hotspots, $PM_{2.5}$ and PM_{10} concentrations and the number of mortalities attributable to $PM_{2.5}$ decreased in the year after the strict policy was implemented. Yabueng and her colleagues also reported a reduction in $PM_{2.5}$ concentrations after the legal enforcement (Yabueng *et al*., 2020). $PM_{2.5}$ and PM_{10} concentrations, however, increased after 2017, despite some measures being implemented, such as allowing the use of reserved forests for living, addressing dust pollution problems and managing the sugarcane preharvest (Fig. 1).

The main conclusion from the existing and current policies on vegetation fire events to reduce air pollution is that policies that were strictly implemented and legally enforced were effective in reducing burning activities, air pollution and health impacts. These policies may not be sustainable, however, as the number of fire hotspots and $PM_{2.5}$ and PM_{10} levels increased subsequently. The low effectiveness of these policies may be due to a lack of details on enforcement, or low participation by the people. Moreover, policies on vegetation fire events targeting different settings should be considered for reducing air pollution and its health impacts. The studies reviewed focused mostly on policies related to crop and agricultural burning practices (e.g., rice and sugarcane). A previous study, however, showed forest fires to be the main source of PM emissions in UNT (Phairuang *et al*., 2017). Policies and actions that prioritize specific dominant areas where burning occurs might have a greater impact on air pollution and human health.

3.2 Priority Research and Information Needs that Can Better Prepare Managers, Policymakers and the Public to Reach Informed Decisions Related to Air Pollution from Vegetation Fire Events on Human Health.

The findings from this study's literature review are categorized into two groups: health effects from air pollution due to vegetation fire events, and effects of fire policies on health outcomes. Table 3 summarizes nine studies examining the effects of air pollution from fire events and policies on human health.

3.2.1 Health Effects from Air Pollution Due to Vegetation Fire Events

In this section, exposure assessment and health outcomes from the reviewed studies are summarized and data/research gaps are identified. All of the studies used continuous air pollution concentration data in their analyses, but they differed in how they defined air pollution from vegetation fires. Most studies used a temporal indicator to assume that air pollution was mainly from fire events during specific periods (Wiwanitkit, 2007; Mueller *et al*., 2020; Uttajug *et al*., 2022; Prapamontol *et al*., 2023). Some studies used fire hotspot data from satellites (Mueller *et al*., 2021), or a threshold value of PM_{10} combined with fire hotspots (Uttajug *et al*., 2021). The remaining studies performed analyses using air pollution concentrations without defining how they assessed exposure to vegetation fire events (Wiwatanadate and Liwsrisakun, 2011; Vajanapoom *et al*., 2020; Pothirat *et al*., 2021).

For the health outcomes, short-term exposure and long-term exposure were considered in this study as different in duration (short-term: hours to weeks, long-term: months to years) and health outcomes of interest. The findings revealed that eight studies were conducted to examine short-term effects of exposure to air pollution from fire events using symptom diagnosis, surveys, surveillance, hospital visits and mortality. Only one study investigated the long-term effects of exposure to air pollution from fire events using birth weight as a health outcome (Mueller *et al*., 2021).

The findings showed that most of the studies focused on short-term health effects, but a few explored the long-term effects of exposure to air pollution from vegetation fire events. A previous study reported a high incidence of lung cancer in the northern region compared to other regions of Thailand (Virani *et al*., 2017). Smoking and air pollution are well-known risk factors for lung cancer. Despite a decreasing trend in smoking in Thailand (Aungkulanon *et al*., 2019), the northern area still has a higher incidence of lung cancer. So far, however, no studies have examined the effects of long-term exposure to air pollution from vegetation fire events on lung cancer in this region. Understanding the role of air pollution from burning on the cancer burden may help inform policymakers and prompt preventative health policies in the area. Based on this gap in the findings, there is a need for cohort data, as well as an accurate and comprehensive assessment of exposure to air pollution from vegetation fire events in UNT.

Table 3 Summary of studies on the effects of air pollution from burning events and policies on human health.

Author (year)	Location	Study period	Implemented policy	Exposure assessment	Health outcome	Methods	Key findings
Wiwanitkit (2008)	Chiang Mai, Thailand	2007	NA	PM_{10}	Influenza	Correlation test	Neutral correlation
Wiwatanadate and Liwsrisakun (2011)	Chiang Mai, Thailand	2005–2006	NA	PM_{10}, SO_2, NO_2, O_3, and CO	1) Peak expiratory flow rates 2) Symptoms in asthmatics	Panel study 1) General linear mixed regression 2) Generalized estimating equations	1) Positive association 2) Null association
Mueller *et al.* (2020)	Northern Thailand	2014–2017	NA	Binary indicator of intensive burning	Hospital visits for respiratory and cardiovascular diseases	Time series analysis with generalized linear regression	Positive association
Vajanapoom *et al.* (2020)	Chiang Mai, Thailand	2002–2016	Haze control measures (2008–2011)	PM_{10}, SO_2, NO_2, O_3, and CO	Mortality	Time- stratified case-crossover analysis fitted with conditional logistic regression	Non-significant reduction in health outcomes
Mueller *et al.* (2021)	All provinces in Thailand, except for Bangkok	2015–2018	NA	PM_{10} and fire hotspot count	Birth weight: 1) Continuous variable 2.) Binary variable of low birth weight (< 2,500 grams)	Semi-ecological study design with 1) linear and 2) logistic regression	1) Reverse association 2) Null association
Pothirat *et al.* (2021)	Chiang Mai, Thailand	2016–2018	NA	$PM_{2.5}$ and PM_{10}	Mortality	Time series analysis with generalized linear regression	Positive association
Uttajug *et al.* (2021)	Northern Thailand	2014–2018	NA	PM_{10} (burning days identified)	Hospital visits by children	Time-stratified case-crossover analysis fitted with conditional logistic regression	Positive association
Uttajug *et al.* (2022)	Northern Thailand	2014–2018	Burning ban in forest areas (2016)	PM_{10}	Hospital visits for respiratory diseases	Interrupted time series analysis	Significant reduction in health outcomes
Prapamontol *et al.* (2023)	Northern Thailand	Aug.–Sep. 2017 and Feb.– Mar. 2018	NA	PM_{10} and O_3	Respiratory infections	Multilevel logistic regression	Positive association

3.2.2 Effects of Policies on Burning on Health Outcomes

Among the nine epidemiological studies, two were conducted to investigate the effects of policies on vegetation fire events on health outcomes. A study conducted by Vajanapoom and her team found a non-significant reduction in mortality after the implementation of haze control measures during 2008–2011 (Vajanapoom *et al.*, 2020). Another study reported a significant reduction in hospital visits due to respiratory diseases when a policy banning burning in forest areas was enforced in 2016 (Uttajug *et al.*, 2022b).

Based on the above findings, additional research is needed to investigate the effects of longer term programs to regulate vegetation fire events on health outcomes. Moreover, the role of individual and neighborhood socioeconomic status on exposure and health should be considered together with environmental policies in future studies. This integration may be important in reducing exposure to air pollution at the community and individual levels (Giles *et al.*, 2011).

4. Conclusions

This study reviewed previous studies and compiled several pieces of information to address how existing and current policies on vegetation fire events affect air quality and its influence on health in upper northern Thailand. It also examined the need for priority research and information related to policies on fire events and their effects on health. This study found that strict regulations had a significant impact on both air pollution and health impacts once they were implemented. However, they had low effectiveness, as PM concentrations and the health burden have remained the same during the past decade. Air pollution from vegetation fire events had short-term negative health impacts on the people living in UNT, but there was no evidence of chronic effects. Future studies should consider longer-term interventions by policies and integrate the factors that might affect exposure levels when examining the beneficial effects of policies on health outcomes.

Acknowledgement

This study was supported by JSPS KAKENHI Grant Number 22K21197.

References

Arunrat, N., Pumijumnong, N. and Sereenonchai, S. (2018) Air-pollutant emissions from agricultural burning in Mae Chaem Basin, Chiang Mai Province, Thailand. *Atmosphere*, 9: 145.

Aungkulanon, S., Pitayarangsarit, S., Bundhamcharoen, K., Akaleephan, C., Chongsuvivatwong, V., Phoncharoen, R. and Tangcharoensathien, V. (2019) Smoking prevalence and attributable deaths in Thailand: predicting outcomes of different tobacco control interventions. *BMC Public Health*, 19: 984.

Charusombat, P. (2023) ASEAN cooperation on transboundary haze pollution: The perspective of institutional incremental change. *Journal of Environmental Information Science*, 2022: 1–12.

Cheong, K.H., Ngiam, N.J., Morgan, G.G., Pek, P.P., Tan, B.Y., Lai, J.W., Koh, J.M., Ong, M.E.H. and Ho, A.F.W. (2019) Acute health impacts of the Southeast Asian transboundary haze problem-A review. *International Journal of Environmental Research and Public Health*, 16.

Forest Fire Control Division (2003) Forest Fire Description. http://www.dnp.go.th/forestfire/Eng/description.htm (accessed 12 September 2023)

Giles, L.V., Barn, P., Kunzli, N., Romieu, I., Mittleman, M.A., van Eeden, S., Allen, R., Carlsten, C., Stieb, D., Noonan, C. *et al.* (2011) From good intentions to proven interventions: effectiveness of actions to reduce the health impacts of air pollution. *Environmental Health Perspectives*, 119: 29–36.

Junpen, A., Pansuk, J. and Garivait, S. (2020) Estimation of reduced air emissions as a result of the implementation of the measure to reduce burned sugarcane in Thailand. *Atmosphere*, 11: 366.

Kumar, I., Bandaru, V., Yampracha, S., Sun, L. and Fungtammasan, B. (2020) Limiting rice and sugarcane residue burning in Thailand: Current status, challenges and strategies. *Journal of Environmental Management*, 276: 111228.

Lualon, U., Ledpornsuttirat, N., Zusman, E. and Sano, D. (2013) Environmental governance and short-lived climate pollutants (SLCPs): the case of open burning in Thailand. Institute for Global Environmental Strategies, *IGES Working Paper No. 2013-03*.

Mueller, W., Loh, M., Vardoulakis, S., Johnston, H.J., Steinle, S., Precha, N., Kliengchuay, W., Tantrakarnapa, K. and Cherrie, J.W. (2020) Ambient particulate matter and biomass burning: an ecological time series study of respiratory and cardiovascular hospital visits in northern Thailand. *Environmental Health*, 19: 77.

Mueller, W., Tantrakarnapa, K., Johnston, H.J., Loh, M., Steinle, S., Vardoulakis, S. and Cherrie, J.W. (2021) Exposure to ambient particulate matter and biomass burning during pregnancy: associations with birth weight in Thailand. *Journal of Exposure Science & Environmental Epidemiology*, 31, 672–682.

Office of the Council of State of Thailand ed. (2016) National Reserved Forests Act (No. 4), B.E. 2559.

Phairuang, W., Hata, M. and Furuuchi, M. (2017) Influence of agricultural activities, forest fires and agro-industries on air quality in Thailand. *Journal of Environmental Sciences*, 52: 85–97.

Phung, V.L.H., Uttajug, A., Ueda, K., Yulianti, N., Latif, M.T. and Naito, D. (2022) A scoping review on the health effects of smoke haze from vegetation and peatland fires in Southeast Asia: Issues with study approaches and interpretation. *PLoS ONE*, 17: e0274433.

Pollution Control Department (2019) Standard operating procedure for northern haze response (Ministry of Natural Resource and Environment). Retrieved from: http://air4thai.com/tagoV2/tago_file/books/book_file/b2b90b38b2b1026ed2c29b001e17d05f.pdf (accessed 5 September 2023)

Pothirat, C., Chaiwong, W., Liwsrisakun, C., Bumroongkit, C., Deesomchok, A., Theerakittikul, T., Limsukon, A., Tajarernmuang, P. and Phetsuk, N. (2019) Acute effects of air pollutants on daily mortality and hospitalizations due to cardiovascular and respiratory diseases. *Journal of Thoracic Disease*, 11: 3070–3083.

Pothirat, C., Chaiwong, W., Liwsrisakun, C., Bumroongkit, C., Deesomchok, A., Theerakittikul, T., Limsukon, A., Tajarernmuang, P. and Phetsuk, N. (2021) The short-term associations of particular matters on non-accidental mortality and causes of death in Chiang Mai, Thailand: a time series analysis study between 2016–2018. *International Journal of Environmental Health Research*, 31: 538–547.

Prapamontol, T., Norback, D., Thongjan, N., Suwannarin, N., Somsunun, K., Ponsawansong, P., Radarit, K., Kawichai, S. and Naksen, W. (2023) Respiratory infections among junior high school students in upper northern Thailand: The role of building dampness and mould, biomass burning and outdoor relative air humidity (RH). *Environmental Research*, 231: 116065.

Ramakreshnan, L., Aghamohammadi, N., Fong, C.S., Bulgiba, A., Zaki, R.A., Wong, L.P. and Sulaiman, N.M. (2018) Haze and health impacts in ASEAN countries: a systematic review. *Environmental Science and Pollution Research International*, 25: 2096–2111.

Targino, A.C., Krecl, P., Johansson, C., Swietlicki, E., Massling, A., Coraiola, G.C. and Lihavainen, H. (2013) Deterioration of air quality across Sweden due to transboundary agricultural burning emissions. *Boreal Environment Research*, 18(1): 19.

Thirumalai, K., DiNezio, P.N., Okumura, Y. and Deser, C. (2017) Extreme temperatures in Southeast Asia caused by El Nino and worsened by global warming. *Nature Communications*, 8: 15531.

Uttajug, A., Ueda, K., Honda, A. and Takano, H. (2022a) Estimation of hospital visits for respiratory diseases attributable to PM(10) from vegetation fire smoke and health impacts of regulatory intervention in Upper Northern Thailand. *Scientific Reports*, 12: 18515.

Uttajug, A., Ueda, K., Oyoshi, K., Honda, A. and Takano, H. (2021) Association between PM(10) from vegetation fire events and hospital visits by children in upper northern Thailand. *Science of The Total Environment*, 764: 142923.

Uttajug, A., Ueda, K., Seposo, X.T., Honda, A. and Takano, H. (2022b) Effect of a vegetation fire event ban on hospital visits for respiratory diseases in Upper Northern Thailand. *International Journal of Epidemiology*, 51: 514–524.

Uttajug, A., Ueda, K., Seposo, X.T., Phosri, A., Phung, V.L.H. and Ahmad Tajudin, M.A.B. (2023) The effects of co-exposure to air pollution from vegetation fires and extreme heat on mortality in Upper Northern Thailand. (In preparation for submission)

Vadrevu, K.P., Lasko, K., Giglio, L., Schroeder, W., Biswas, S. and Justice, C. (2019) Trends in Vegetation fires in South and Southeast Asian Countries. *Scientific Reports*, 9: 7422.

Vajanapoom, N., Kooncumchoo, P. and Thach, T.Q. (2020) Acute effects of air pollution on all-cause mortality: a natural experiment from haze control measures in Chiang Mai Province, Thailand. *PeerJ*, 8: e9207.

Virani, S., Bilheem, S., Chansaard, W., Chitapanarux, I., Daoprasert, K., Khuanchana, S., Leklob, A., Pongnikorn, D., Rozek, L.S., Siriarechakul, S. *et al*. (2017) National and subnational population-based incidence of cancer in Thailand: assessing cancers with the highest burdens. *Cancers (Basel)*, 9(8): 108.

Wiwanitkit, V. (2008) PM10 in the atmosphere and incidence of respiratory illness in Chiangmai during the smoggy pollution. *Stochastic Environmental Research and Risk Assessment*, 22: 437–440.

Wiwatanadate, P. and Liwsrisakun, C. (2011) Acute effects of air pollution on peak expiratory flow rates and symptoms among asthmatic patients in Chiang Mai, Thailand. *International Journal of Hygiene and Environmental Health*, 214: 251–257.

Yabueng, N., Wiriya, W. and Chantara, S. (2020) Influence of zero-burning policy and climate phenomena on ambient PM2.5 patterns and PAHs inhalation cancer risk during episodes of smoke haze in Northern Thailand. *Atmospheric Environment*, 232: 117485.

Yin, S., Wang, X., Zhang, X., Guo, M., Miura, M. and Xiao, Y. (2019) Influence of biomass burning on local air pollution in mainland Southeast Asia from 2001 to 2016. *Environmental Pollution*, 254: 112949.

Athicha UTTAJUG

Athicha Uttajug, PhD, is a specially appointed assistant professor in the Department of Hygiene, Graduate School of Medicine, Hokkaido University. She completed her PhD in 2021 at the Graduate School of Engineering, Department of Environmental Engineering, Kyoto University. Her specialization lies in environmental epidemiology with a focus on studying the health impacts of air pollution and climate change. Currently, she is engaged in research to investigate the effects of extreme weather events on various health outcomes and healthcare facilities, using statistical modeling.

(Received 12 September 2023, Accepted 26 December 2023)